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Physics of the Solid State

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IONIC CONDUCTIVITY OF NACL AND KCL

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May 1954

The work done in conjunction with this report was an attempt to determine the cause of apparent increases in conductivity in KCL and NaCl crystals. The increase is noted when the crystals are heated to temperatures above 400 degrees centigrade and allowed to remain there for an hour or so. This increase was first noted by Mr. Joseph Aschner and later confirmed by Mr. Dale Compton both working with Harshaw crystals and crystals grown at the University of Illinois. In addition, Mr. Compton noted this effect in a report on conductivity of KCL and NaCl crystals grown by Dr. Pick.

The apparatus (Crystal holder) used for holding the crystals during the measurements made by Mr. Aschner and Mr. Compton was made from a variety of materials. It consisted of a stainless steel sleeve holding platinum coated Nickel contacts. These contacts held the crystal under slight spring tension. The crystal was painted on two sides with "Dag" to form electrodes. The crystal and lower portion of the holder were in the region of highest temperature while the upper portion of the crystal holder was in a cooler atomsphere. The holder and crystal were in an atmosphere of Helium supplied directly from a Helium tank.

The cause of the apparent increase in conductivity was believed to be due to impurities introduced by the holder when heated to the higher temperatures. To investigate this possibility a new holder was designed. This holder was so designed that only Platinum and Vycor were in the high temperature region. Approximately the same pressure was placed on the crystals and the crystals were again painted on two sides with the "Dag"

coating.

The results obtained are included in the form of plots of log conductivity vs reciprocal temperature and the data from which the plots were made is included.

The data given refers to plots on the succeeding pages.

Plot I. NaCl sample from Harshaw.

Dimensions: t - .0435"
A - .0971" x .0820"

Temperature increasing:

T	529°	568°	651°	732°	814°	895°
σ	2.38×10^{-8}	8.51×10^{-8}	7.04×10^{-7}	2.82×10^{-6}	7.78×10^{-6}	3.78×10^{-5}
T	976°	°K				
σ	1.46×10^{-4}	$ohm^{-1}cm^{-1}$				
	Temperature decreasing:					
T	975°	891°	809°	726°	643°	559°
σ	1.39×10^{-4}	2.54×10^{-5}	6.78×10^{-6}	2.48×10^{-6}	5.47×10^{-7}	6.05×10^{-8}
T	515°	°K				
σ	1.47×10^{-8}	$ohm^{-1}cm^{-1}$				

Plot II NaCl sample from Pick (Gottingen)

Dimensions: t - .0805"
A - .1177" x.0900"

Temperature increasing:

T	516°	571°	616°	667°	716°	763°
σ	2.87×10^{-9}	1.78×10^{-8}	5.92×10^{-8}	1.57×10^{-7}	3.2×10^{-7}	6.2×10^{-7}
T	814°	862°	911°			
σ	1.99×10^{-6}	5.8×10^{-6}	2.49×10^{-5}			

Temperature decreasing:

T	880°	798°	744°	687°	632°	575°
σ	1.12×10^{-5}	1.37×10^{-6}	4.9×10^{-7}	2.15×10^{-7}	8.14×10^{-8}	1.87×10^{-8}
T	543°					
σ	5.63×10^{-9}					

Plot III. NaCl sample from Pick. **(Crystal remained at 700°C for two hours)**

Dimensions: t - .0805"
A - .1142" x .0782"

Prior to remaining at 700°C for two hours:

T	514°	569°	618°	668°	715°	765°
σ	3.04×10^{-9}	1.78×10^{-8}	6.3×10^{-8}	1.6×10^{-7}	3.2×10^{-7}	6.4×10^{-7}
T	813°	863°	911°	959°	975°	
σ	1.63×10^{-6}	6.06×10^{-6}	2.45×10^{-5}	8.36×10^{-5}	1.266×10^{-4}	

After remaining at 700°C for two hours:

T	922°	864°	802°	747°	694°	640°
σ	3.38×10^{-5}	7.25×10^{-6}	1.43×10^{-6}	5.74×10^{-7}	2.78×10^{-7}	1.16×10^{-7}
T	585°	532°				
σ	3.12×10^{-8}	1.34×10^{-8}				

Plot IV. KCl sample from **Pick. (Crystal remained at 400°C for two hours)**

Dimensions: t - .0519"
A - .0673" x .0611"

Prior to remaining at 400°C for two hours:

T	517°	571°	619°	668°	716°	764°	813°
σ	3.28×10^{-4}	1.99×10^{-8}	3.12×10^{-8}	7.06×10^{-8}	1.85×10^{-7}	3.47×10^{-7}	8.3×10^{-7}
T	861°	910°	934°				
σ	2.19×10^{-6}	8.78×10^{-6}	1.69×10^{-5}				

After remaining at 400°C for two hours:

T	879°	796°	742°	687°	632°	575°
σ	4.24×10^{-6}	7.72×10^{-7}	3.45×10^{-7}	1.49×10^{-7}	5.59×10^{-8}	1.57×10^{-8}
T	542°	521°				
σ	6.05×10^{-9}	3.28×10^{-9}				

Plot V. KCl sample from Pick. (Crystal left at 700°C for 40 minutes)

Dimensions: t - .0692"
A - .0828" x .0811"

Prior to remaining at 700°C for 40 minutes:

T	500°	548°	603°	660°	715°	770°
σ	8.14×10^{-9}	1.43×10^{-8}	3.69×10^{-8}	8.98×10^{-8}	1.99×10^{-7}	4.33×10^{-7}
T	825°	880°	937°			
σ	1.00×10^{-6}	3.89×10^{-6}	1.53×10^{-5}			

After remaining at 700°C for 40 minutes:

T	909°	855°	801°	748°	693°	638°
σ	7.54×10^{-6}	1.65×10^{-6}	5.36×10^{-7}	2.36×10^{-7}	934×10^{-8}	3.73×10^{-8}
T	585°	533°				
σ	1.54×10^{-8}	3.93×10^{-9}				

Plot VI. KCl sample from Harshaw. (Crystal left at 650°C for one hour)

Dimensions: t - .1348"
A - .1420" x .1564"

Prior to remaining at 650°C for one hour:

T	476°	557°	642°	722°	802°	884°
σ	2.81×10^{-10}	2.52×10^{-9}	1.14×10^{-8}	3.49×10^{-8}	2.62×10^{-7}	3.39×10^{-6}
T	911°					
σ	3.64×10^{-6}					

After remaining at 650°C for one hour:

T	211°	827°	745°	659°	576°	508°
σ	6.88x10-6	7.40x10-7	8.30x10-8	2.08x10-8	4.93x10-9	1.36x10-10

From the data and plots the following results seem to be indicated:

1. The results are the same with the new crystal holder as with the holder used by Mr. Aschner and Mr. Compton and, since great care was taken to see that the holder used here was very clean, it seems that the source of change in conductivity is not due to an introduction of impurities by the holder.

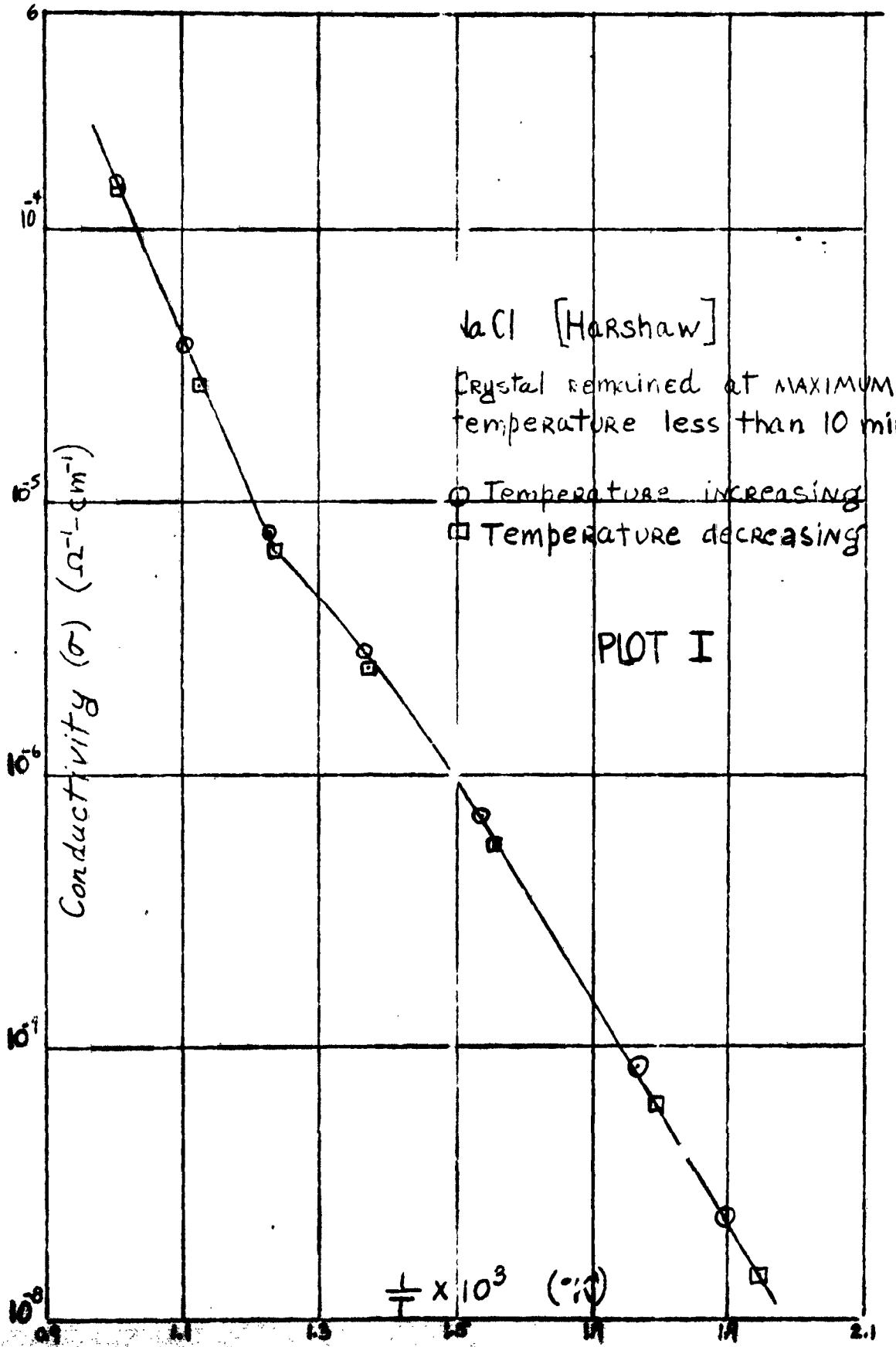
2. The change in conductivity is not apparent unless the crystal is left at temperatures above 400°C for periods of thirty minutes or longer. This was noted for all types of crystals used. This would seem to indicate that either a chemical reaction is occurring that can only take place at higher temperatures or that some plastic deformation is taking place in the crystal. However, it was noted that no measurable change in crystal dimensions occurred. The dimensions of the crystals were measured just prior to and just after each conductivity run.

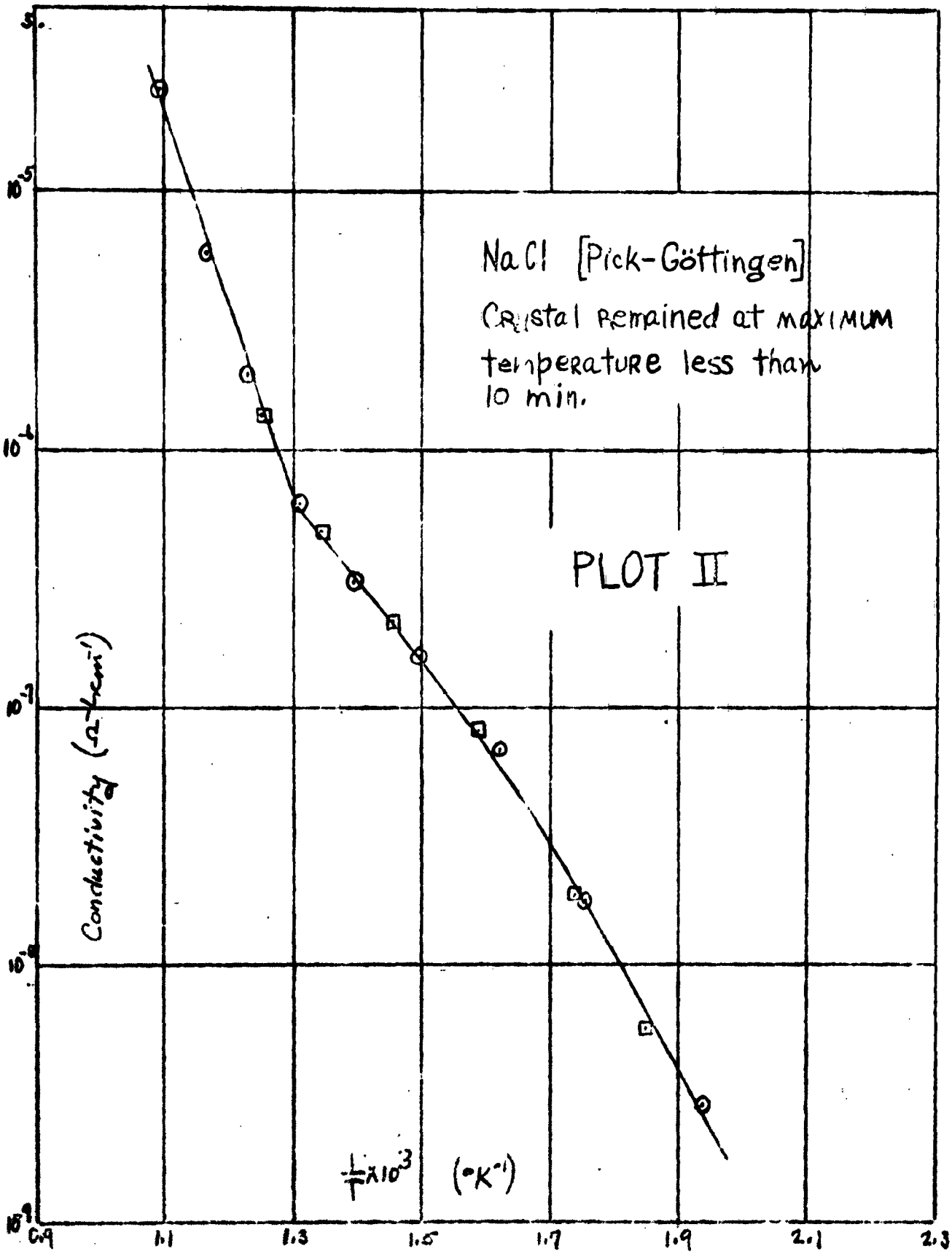
3. The change in conductivity is more apparent in the KCl crystals than in the NaCl crystals.

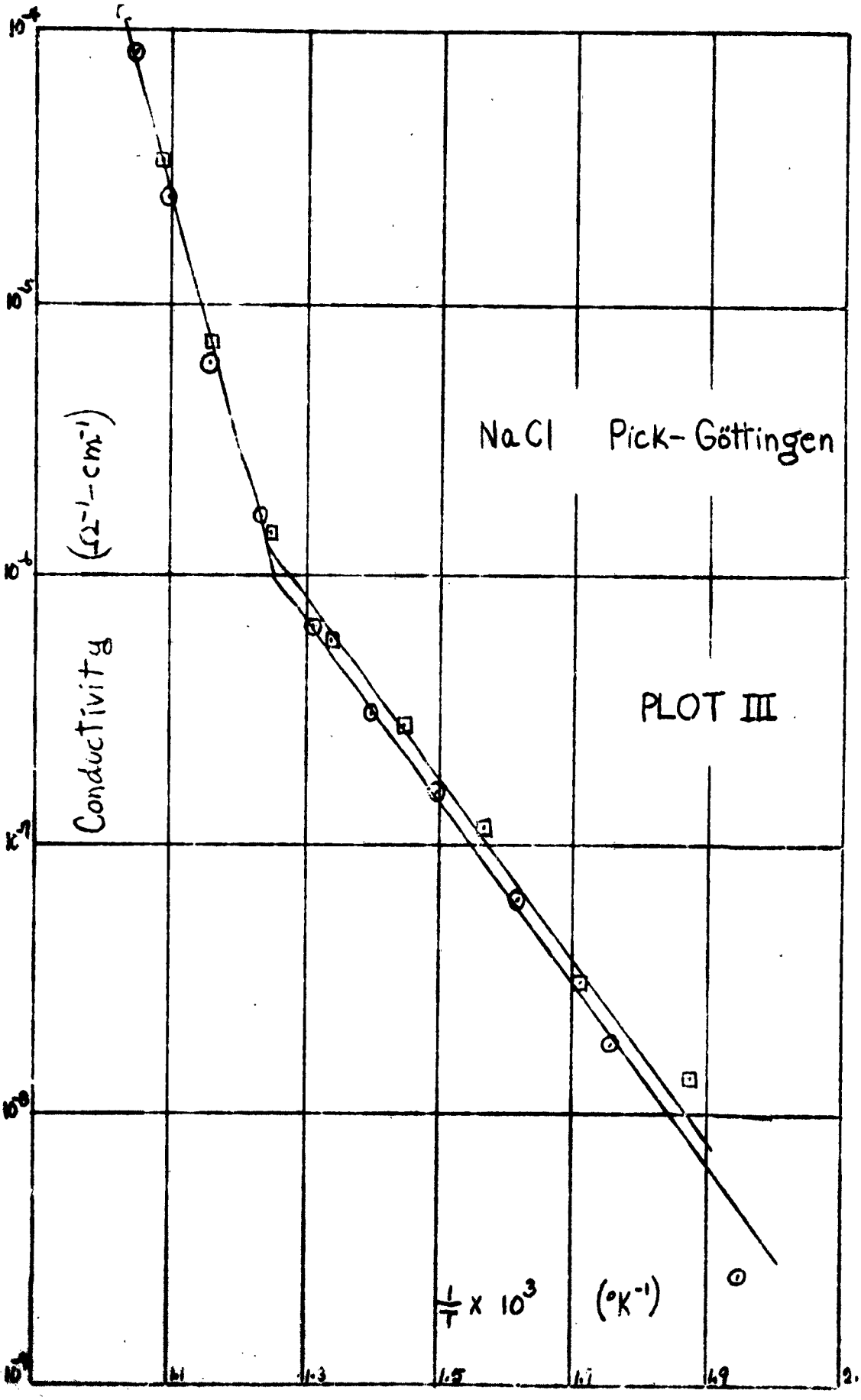
4. Two possible sources of impurity introduction still have not been investigated. The Helium supply, although believed to be very clean from other considerations, could be filtered as a check on a source of impurity introduction. Also, the method of putting electrodes on the crystals should be investigated. A method other than painting with "Dag" might yield fruitful results.

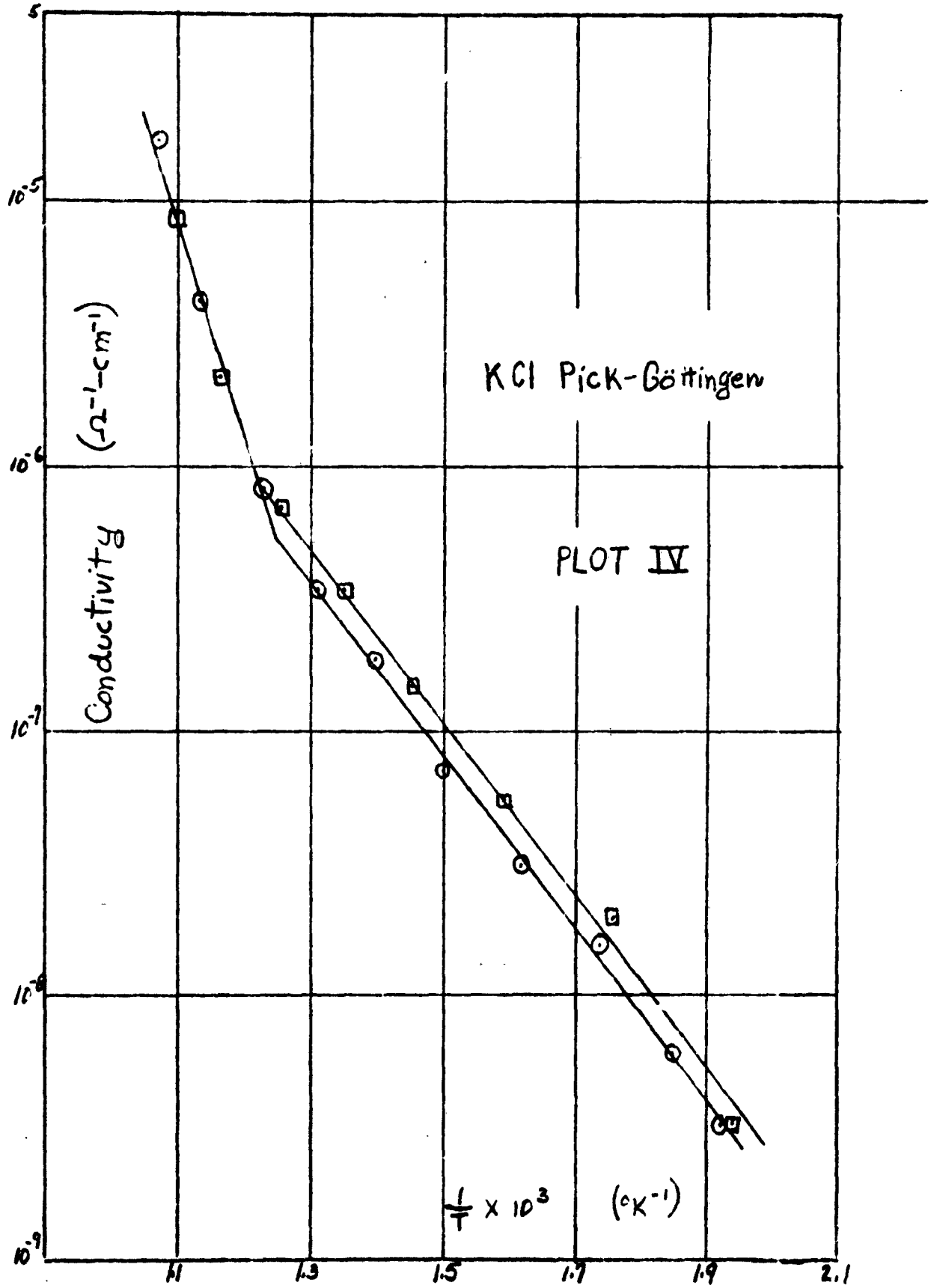
5. The holder used here was used for about 20 conductivity runs over a period of about four months and has not given any electrical or mechanical trouble. Thus it seems to have better operational characteristics than the crystal holder previously used.

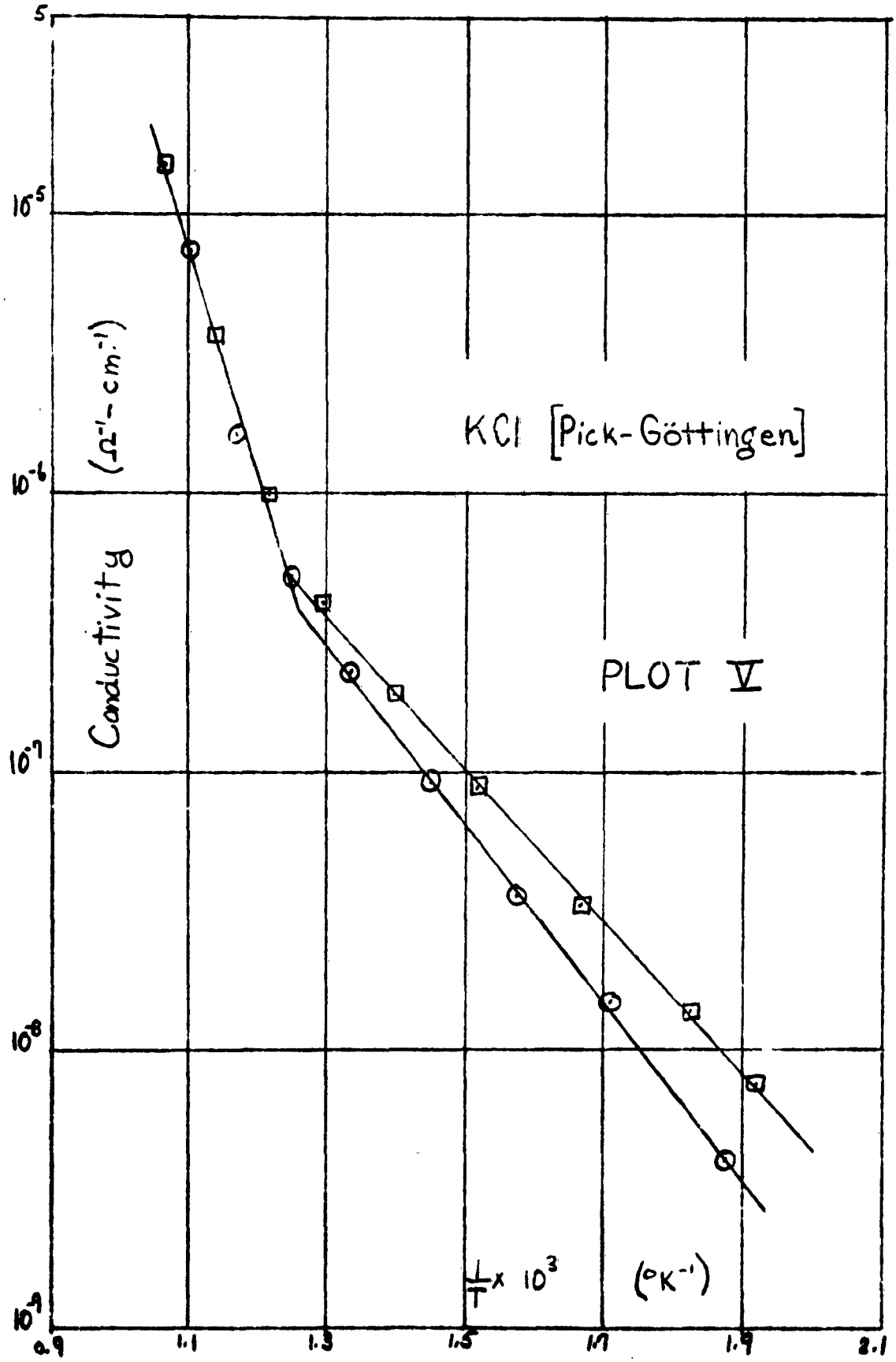
*"Dag" - Dispersion No. 154 (Graphite in Alcohol) Acheson Colloids Corporation.

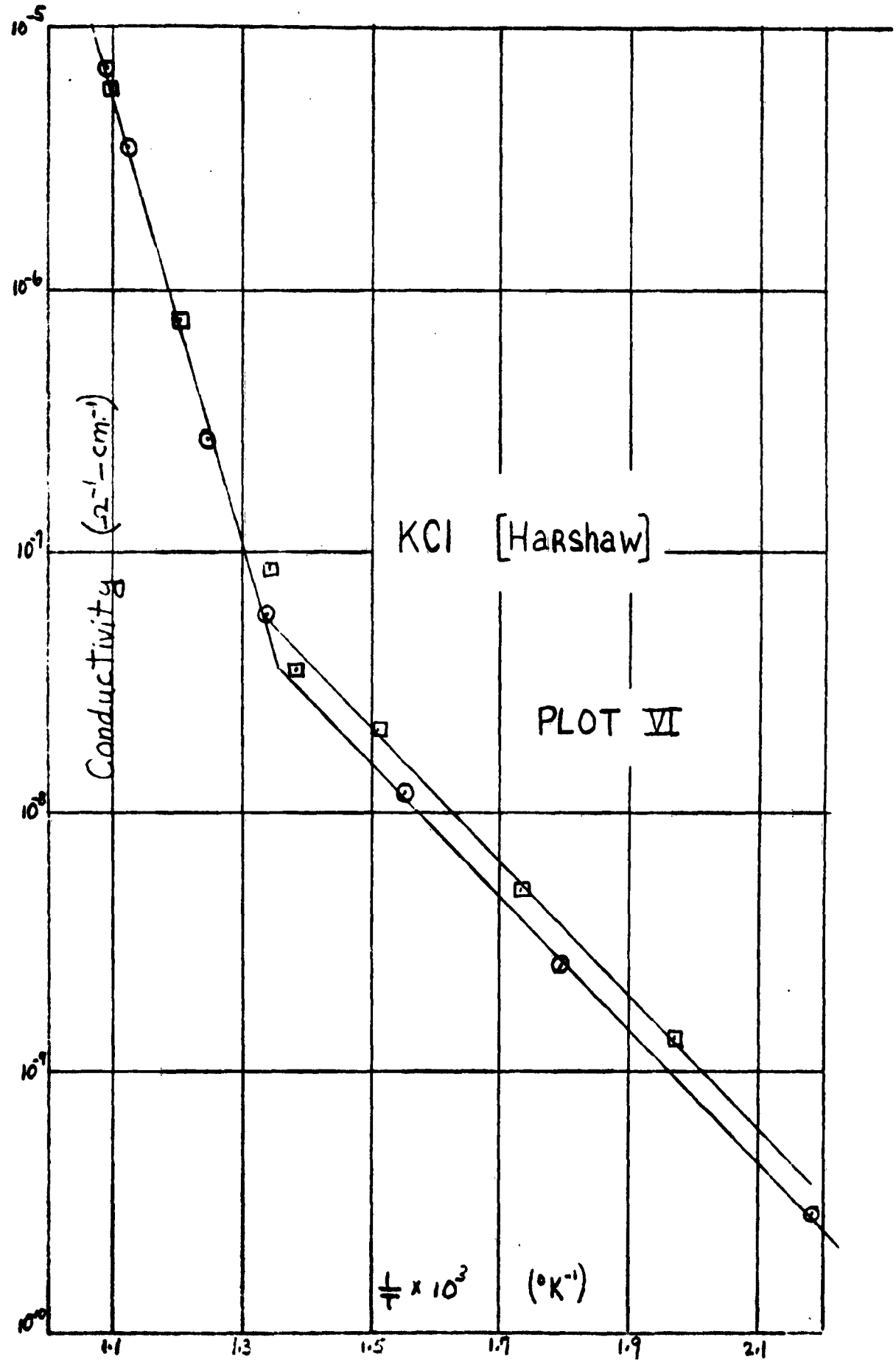

NaCl [Harshaw]
Crystal remained at MAXIMUM temperature less than 10 min.
Temperature increasing
Temperature decreasing
PLOT I
Conductivity (σ) (Ω⁻¹-cm⁻¹)
6
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
1/T x 10³ (°K)
0.9
1.1
1.3
1.5
1.7
1.9
2.1


NaCl [Pick-Göttingen]
Crystal remained at maximum temperature less than 10 min.
PLOT II
Conductivity (Ω⁻¹cm⁻¹)
10⁻¹
10⁻²
10⁻³
10⁻⁴
0.9
1.1
1.3
1.5
1.7
1.9
2.1
2.3
1/T x 10⁻³ (°K⁻¹)


NaCl Pick-Göttingen
PLOT III
Conductivity (Ω⁻¹-cm⁻¹)
1/T x 10³ (°K⁻¹)
1.1
1.3
1.5
1.7
1.9
2.1


KCl Pick-Göttingen
PLOT IV
Conductivity (Ω⁻¹-cm⁻¹)
5
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
1.1
1.3
1.5
1.7
1.9
2.1
1/T x 10³ (°K⁻¹)


KCl [Pick-Göttingen]
PLOT V
Conductivity (Ω⁻¹-cm⁻¹)
5
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
0.9
1.1
1.3
1.5
1.7
1.9
2.1
1/T x 10³ (°K⁻¹)


KCl [Harshaw]
PLOT VI
Conductivity (Ω⁻¹-cm.⁻¹)
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
1.1
1.3
1.5
1.7
1.9
2.1
1/T x 10³ (°K⁻¹)

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